Jet substructure in pp collisions at √s = 13 TeV

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Jet measurements at low $p_T$

Unique opportunity to constrain perturbative and non-perturbative effects with ALICE

New data allows for more differential studies using jet substructure observables
Jet substructure measurements with ALICE

**Dataset:**
- Min. bias: ∫dt = 11.5 nb⁻¹ collected in 2016 + 2017
- Triggered: ∫dt = 4 pb⁻¹ collected in 2017

**Jet trigger**
- ITS + TPC: Charged constituents
  \[ p_{T,\text{cut-off}} = 150 \text{ MeV/c}, \text{for full jets restricted to EMCAL acceptance} \]

**EMCAL:** Neutral constituents
\[ E_{\text{cut-off}} = 300 \text{ MeV}, |\eta| < 0.7 \text{ and } 1.4 < \phi < 3.1 \text{ (rad)} \]

**Jet reconstruction:**
- Anti-\( k_T \) algorithm, E-scheme
- \( R=0.2 \text{ – } R=0.5 \)
- 30 GeV/c < \( p_T < 200 \text{ GeV/c} \)
Based on neutral energy in EMCal in a jet patch corresponding to $R \sim 0.3$

No trigger bias:
- Low threshold: 60 GeV/$c$
- High threshold: 80 GeV/$c$

Bias free region region defines $p_T$-ranges where triggers contribute to substructure measurements.
Charged jets: only including charged constituents at particle level

Neutral jets: Full jet energy at particle level
Differential jet cross section in pp collisions at $\sqrt{s} = 13$ TeV for track-based jets

Good agreement with generators at low-$p_T$
Ratios of jet cross sections with different $R$ are sensitive to intra-jet broadening

In good agreement with PYTHIA and POWHEG
Charged jet production as function of the charged particle multiplicity

Study correlation between hard interaction and event activity

Weak $p_T$-dependence in different multiplicity bins

Y. Hou, Poster session
Charged jets production as function of the multiplicity

Weak multiplicity dependence in ratio of the jet spectra

Similar trends observed with PYTHIA

Y. Hou, Poster session
Extract the hard components of a jet

- Recursively removing large-angle soft radiation
- Method:
  - Recluster jet (with Cambridge/Aachen algorithm)
  - Decluster tree
  - Remove softer branch until SoftDrop condition is fulfilled

\[ z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{cut} \]

- Grooming controlled by \( z_{cut} \) and \( \beta \)

M. Dasgupta, A. Fregoso, S. Marzani, G. P. Salam JHEP09 (2013) 029,
A. Larkoski, S. Marzani, G. Soyez, J. Thaler JHEP 1405 (2014) 146
**Expectations from theory**

- $z_g$ directly related to the splitting function
- $p_T$-dependence:
  - Not expected (directly connected to QCD $z$ kernel)
- $R$-dependence
  - Different perturbative / non-perturbative effects dominate for different $R$

**Related example: groomed mass**

\[
\begin{align*}
460 < p_T, m_{MDT} < 550 \text{ GeV} \\
\text{At} \begin{cases} 
\delta p_t \sim \ln(R) \\
\delta p_t \sim -\frac{1}{R}
\end{cases}
\end{align*}
\]

S. Marzani, L. Schunk, G. Soyez JHEP 07 (2017) 132

Substructure allows to isolate ingredients of the theoretical description of jet production
Instrumental response of the $z_g$ shape

Bayesian unfolding in 2D used to correct back to particle level

$z_g$ response has wing / off-diagonal entries

$pp \sqrt{s} = 13$ TeV, PYTHIA8(Monash2013)

Anti-$k_T$, $R=0.2$

$p_{\text{track}}^T > 0.15 \text{ GeV/c}, E_{\text{cluster}} > 0.3 \text{ GeV}$

$|\eta_{\text{track,cluster}}| < 0.7, |\eta_{\text{jet}}| < 0.5$

ALICE Simulation

$p_{\text{part}}^T < 60.0 \text{ GeV/c}$

$p_{\text{track}}^T > 0.15 \text{ GeV/c}, E_{\text{cluster}} > 0.3 \text{ GeV}$

$|\eta_{\text{track,cluster}}| < 0.7, |\eta_{\text{jet}}| < 0.5$

SoftDrop: $z_{\text{cut}} = 0.1, \beta = 0$
Groomed momentum fraction vs $\rho_T$

- $\rho_T$-dependence for small radii
  - Trend to larger $z_g$ at low $\rho_T$ and towards smaller $z_g$ at high-$\rho_T$
- No $p_T$ dependence or larger jet radii
- Generators reproduce $\rho_T$-dependence well

No underlying event subtraction applied
- Grooming already removes the soft component
- No underlying event subtraction in PYTHIA as well
Groomed momentum fraction vs $R$

Low $p_T$: Shape different for small and large jet radii
- Trend towards more asymmetric splitting for larger $R$
- At the same $p_T$ larger jets capture more soft large-angle radiation
- Sensitivity to non-perturbative effects / underlying event

High $p_T$: $z_g$ independent of $R$
- Dominant part of the jet energy in core, small influence of large angle radiation

PYTHIA reproduces the trend at low $p_T$ very well
Conclusions and outlook

• Measurement of jet substructure in a wide range of jet radii and jet $p_T$
• Ratios of cross sections of various jet radii in good agreement with PYTHIA and PYTHIA+POWHEG
• No dependence of $z_g$ on the jet $p_t$ except in the lowest $p_T$-bins
• Weak dependence of charged jet production on the charged particle multiplicity in pp collisions

• Outlook: Measurement to be extended with more shapes ($Rg$, number of dropped branches, ...)

Markus Fasel (ORNL) | Hard Probes 2018, Oct 1st-5th, 2018